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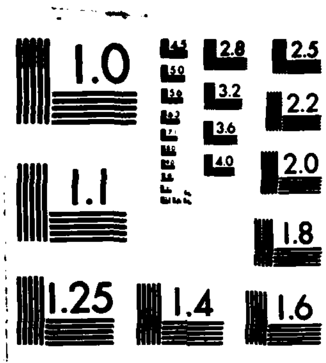

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The main element of this final report is a discussion of the development of the trace method for determining the acoustic properties of the ocean bottom sediments and basement. In addition a method is reported for the uniform determination of the continuous modal contribution in a normal mode expansion for the second term in the geometrical acoustic expansion near a smooth caustic. Originator-supplied keywords include:

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The work on this contract has forcussed on developing a method to determine the acoustic parameters of the ocean sediments and basement. The methods are indirect in that they attempt to determine the properties (density and sound speeds as a function of depth) from measurement of the field reflected from the ocean bottom.

The initial paper[1] in this series shows how to use the methods of one-dimensional inverse scattering theory, in particular the new approach of Deift and Trubowitz [Comm. Pure Appl. Math. XXXII, 121-251 (1979)], to recover the sound speed for the case of a stratified ocean with a pressure release surface driven by a harmonic point source at a finite depth from a measurement of the normal derivative at the pressure release surface. The method is not a perturbation technique. For comparison, this same problem is examined when the sound speed is slightly perturbed from unity using a technique of Cohen and Bleistein [SIAM J. App. Math. 32, 784-799 (1977) and Geophysics 44, 1077-1087 (1979)]. The trace method of Deift and Trtubowitz was introduced to examine the quantum mechanical problem where it was reasonable to assume that the sound speed approached the same known value at depth and in the ocean. This is in general not the case, but their method was extended to the "geophysical" acoustic case in the next paper[2].

In this analysis the following problem is considered: A point harmonic source at frequencies ω_1 and ω_2 is located in the region $z < 0$, where the assumption is made that both the sound speed and density profiles are known. For $z > 0$ the the sound speed and density profilefs are unknown. These two profiles are recovered from a measurement of the pressure field for all r at some fixed depth $z < 0$ at the two frequencies. Trace formula methods are used. The following assumptions are needed: First, $c(z)$ and $\rho(z)$ approach c_1, ρ_1 as $\to -\infty$, and c_2, ρ_2 as $z \to +\infty$, and although c_2, ρ_2 are not known, it must be known that $c_2 > c_1$. Second, the angular frequency of the source must be such that no trapped modes are excited. While the sound speed $c(z)$ can be complex, the limiting values c_1 and c_2 must be real. If $c(z)$ also depends on frequency and the form of the dependence is known, say, $c(z) = c_R(z) + i\omega^{\lambda(z)}c_I(z)$, then $c_R(z), c_I(z)$, and $\lambda(z)$ can be recovered.

Explicit expressions are obtained in the realistic ase when $c_I(z)$ is not large. If a density is known and $c_I(z) = 0$, then only a measurement at one frequency is required. Two numerical examples are given; in both examples $\rho(z) \equiv 1$ and $c(z)$ is real. The first example is for a monotonically increasing profile and the second has a low velocity zone. Typical sediment parameters are used.

When the ocean bottom is modeled as a fluid, then only the sound speed and density need to be recovered. But if the sediments and basement support shear waves; then they must be modelled elastically. This means that two wave speeds and the density must be recovered. Before this problem was examined the trace method was applied to a simpler set of equations which nonetheless supported N-different types of waves, rather than just two.[3]

Trace formulas are derived for the coefficients of a matrix differential equation representing wave propagation in a medium which supports N types of waves. In general these waves are coupled to each other but are assumed to become uncoupled as $|z| \to \infty$, but unknown for $z > 0$. A point source is located in the region $z < 0$ and the point source field is measured in the same region. These measurements yield a reflection coefficient which is then used in the trace formulas, derived in the paper, to recover the two matrix coefficients for $z > 0$. The unique features of this work are a derivation of the trace formula in which the Jost functions are not needed, an alternate measurement method based on an impedance concept and a trace equation based on an impedance concept.

These results have been presented as invited talks at the

(1) Spring 1983 meeting of the Acoustical Society of America.

(2) Spring 1983 meeting of the Society of Photo-Optical Instrumentation Engineers.

This talk also appeared as a paper in their journal[4] and indicates that the method can be used in contexts other than acoustics.

(3) Spring 1983, American Mathematical Society and Society of Industrial and Applied Mathematics.

This talk also appeared as a chapter in Vol. 14 of their series [5].

This analysis is being extended to the elastic case and has been

partially presented as an invited talk at the Spring 1984, International Conference on Acoustic and Elastic Inverse Scattering held at Cornell University.

Building of some earlier work by Stickler and Ammicht[6] (in an earlier phase of this contract) an expansion was found for the asymptotic evaluation of the continuous spectrum for a normal model expansion of the pressure field in a stratified ocean[7].

The determination of the continuous spectral contribution for a stratified ocean acoustic model can be a difficult and expensive numerical task. A uniform asymptotic technique has been used to calculate the pressure field for the Pekeris model. It is uniform in the sense that it is valid as a mode passes through cutoff. The basic idea of the technique is to exploit the effect of the various singular points of the integrand representing the continuous spectrum. This idea has been further exploited to describe the continuous spectrum contribution for a general stratified ocean. Numerical examples show that this technique is both accurate and fast.

Again building on some work sponsored in an earlier phase of this contract[8], where the leading term was calculated for the temporal response of the acoustic pressure near a smooth caustic, the initial phase of the necessary calculation to determine the second term was completed[9].

One method to estimate the validity of the leading term in the geometrical acoustics expansion is to calculate the second term in the expansion. This second term plays an essential role in the construction of the second term in Ludwig's uniform smooth caustic ansatz and in the construction of the progressing wave smooth caustic ansatz. Therefore, the determination of this term is important in the assessment of each of these expansions. Expressions for this second term are derived valid for arbitrary index profilefs near the source point and near a smooth caustic. Numerical examples are presented for the n^2-linear profile. These results show that near the source the second term is not singular, but near the caustic it is more singular than the leading order term.

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